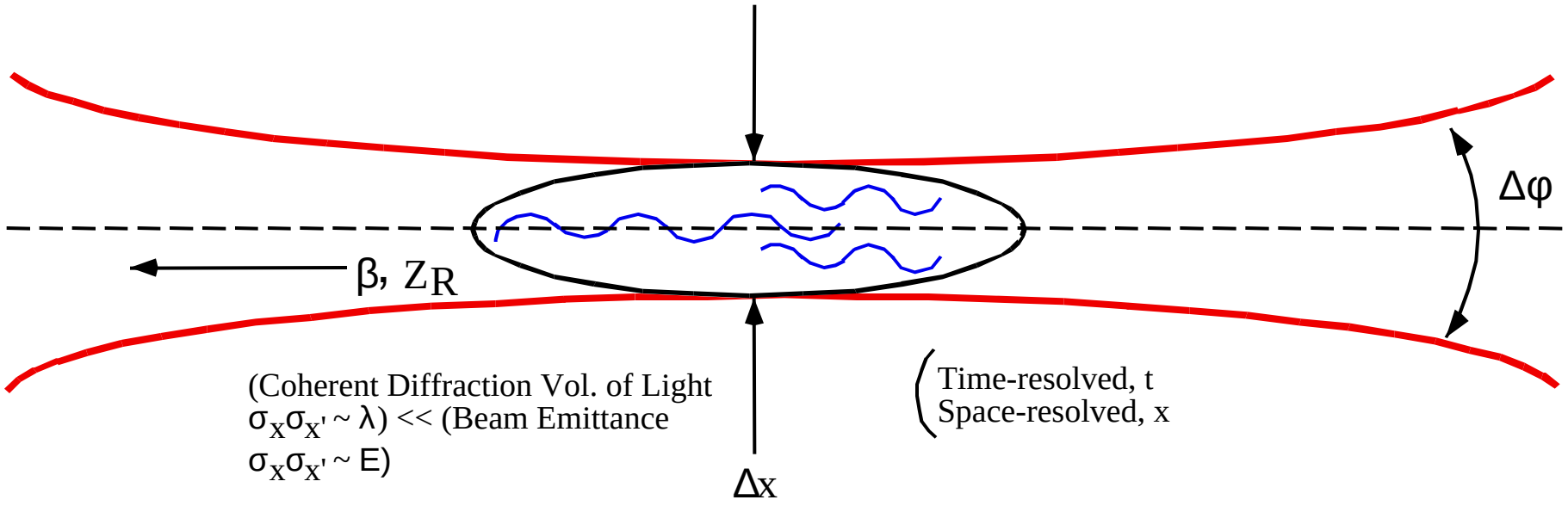
Particle & Radiation Beam



Particle

E

$\Delta x_e, \Delta \varphi_e$

β

$\Delta x_e \Delta \varphi_e = 2\pi\varepsilon_{rms}$

Radiation

$\hbar\omega$

$\Delta x_r, \Delta \varphi_r$

Z_r

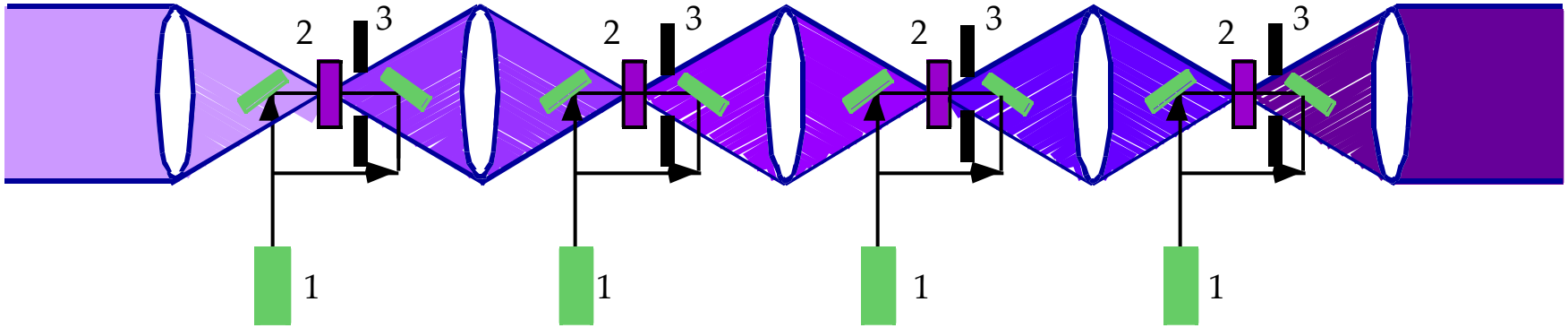
$\Delta \varphi_r \cdot \Delta x_r = \lambda/2$

$$\Delta_x = \sqrt{2\pi}\ \sigma_x, \text{ etc.}$$

$$\sigma_r \sigma_{r'} = \lambda/4\pi$$

A Schematic of Optical Amplifier

Average power	2 W
Bandwidth, FWHM	4×10^{13} Hz
Total gain	44 dB



1 - argon-ion laser

2 - Ti : sapphire crystal

3 - aperture

Optical Properties of Ti : sapphire at 300 k

Fluorescence peak	780 nm
Fluorescence lifetime	3.2 μ s
Saturation intensity	2.4×10^{5} W/cm^2
Bandwidth, FWHM	10^{14} Hz
Refractive index, n	1.76
Temp. coefficient, $\frac{dn}{dT}$	1.3×10^{-5} K^{-1}

TeV 33 Luminosity Enhancement via OSC

- Beam-beam limited luminosity :

$$L = \frac{\gamma}{r_p}\,\xi\,\frac{N_{\bar{p}}}{\beta^*} \qquad (\xi \lesssim 0.025)$$

$$\xi = \frac{r_p N_p}{4\pi\gamma\varepsilon}$$

- Rate of particle loss due to collisions:

$$\dot{N} = 2\,\sigma_{hadron}\,L \qquad \text{(Two IPs)}$$

$$\sim 1.4 \times 10^{6}\ s^{-1} \ @\ 10^{33} cm^{-2} s^{-1}$$

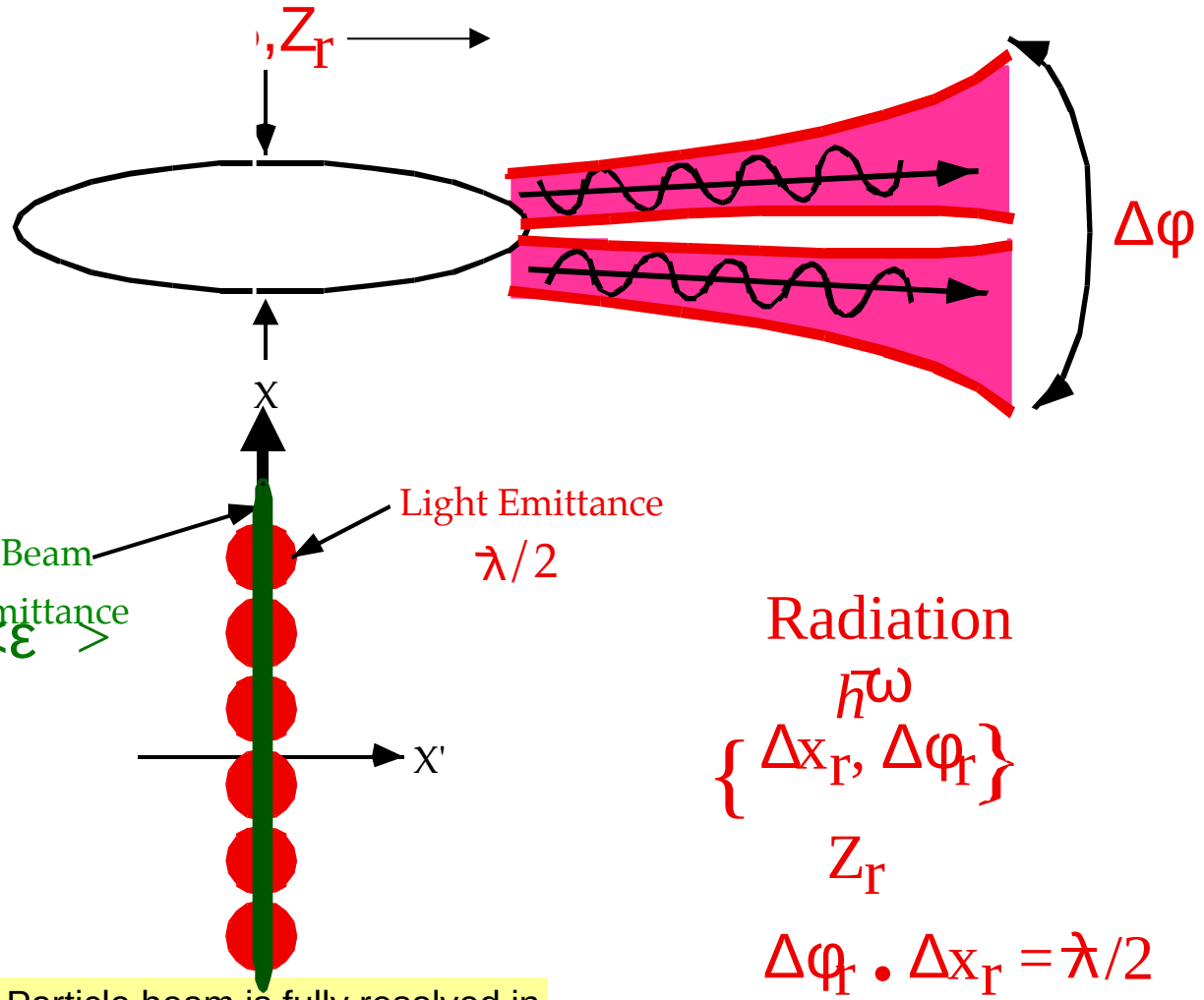
- Optical Stochastic Cooling can provide peak luminosity during 30 hours of store time by reducing the transverse emittance ε, in step with particle loss (thus keeping ξ at its maximum limiting value) :

$$\varepsilon \sim 20\pi \text{ mm mrad} \rightarrow 8\pi \text{ mm mrad}$$

and by reducing the β^* (and hence the longitudinal emittance so that $\sigma_\ell \sim \beta^*$) :

$$\beta^* \sim 35\text{cm.} \rightarrow 15\text{cm.}$$

Transverse Samples



Particle

E

$\{\Delta x_e, \Delta \varphi_e\}$

β

$\Delta x_e \cdot \Delta \varphi_e = 2\pi <\varepsilon>$

Radiation

$\hbar\omega$

$\{\Delta x_r, \Delta \varphi_r\}$

Z_r

$\Delta \varphi_r \cdot \Delta x_r = \lambda/2$

Particle beam is fully resolved in space and time by light beam

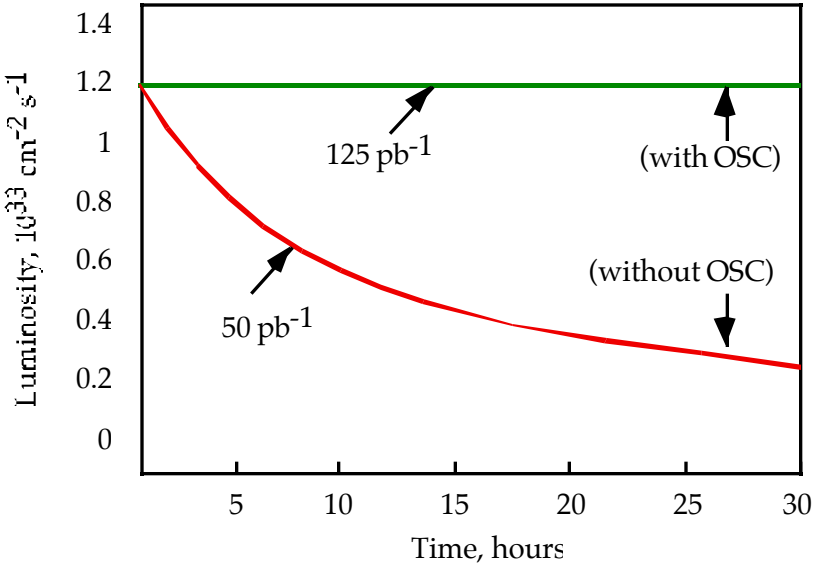
[Coherence Volume of Light < Beam Emittance]

TeV 33 Luminosity Enhancement via OSC (cont'd)

- Finally, with OSC :

$$\int L dt \sim 125\ pb^{-1}$$

(compared with 50 pb^{-1} without OSC)



- If not limited by antiproton accumulation time, colliding beam "runs" longer than 30 hours are also possible, without loss of luminosity.
- If beam-beam effect can possibly be compensated nonlocally by a nonlinear element (electron beam) somewhere else in the ring, further enhancement of luninosity cantake place by allowing larger ξ achieved by reducing ε urther via cooling.
- Possibility of transverse cooling of ε n the Tevatron main ring for an hour following every 30-50 hour allows $\bar{p}$ ccumulation in the collider ring itself, thus easing demands on the Recycler.